RESEARCH DEPARTMENT

A Servo-system for Reducing Amplitude Modulation when the Magnetic Reproducing Head is Separated from the Track

Report No. C.082

Serial No. 1954/12

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

A SERVO-SYSTEM FOR REDUCING AMPLITUDE MODULATION WHEN THE MAGNETIC REPRODUCING HEAD IS SEPARATED FROM THE TRACK

Report No. C.082

Serial No. 1954/12

M. Cooper, B.Sc.

W. Proctor Wilson

(W. Proctor Wilson)

Report No. C.082

A SERVO-SYSTEM FOR REDUCING AMPLITUDE MODULATION WHEN THE MAGNETIC REPRODUCING HEAD IS SEPARATED FROM THE TRACK

Report No. C.082

March 1954

Serial No. 1954/12

A SERVO-SYSTEM FOR REDUCING AMPLITUDE MODULATION WHEN THE MAGNETIC REPRODUCING HEAD IS SEPARATED FROM THE TRACK

SUMMARY

In some applications of magnetic recording, such as storage or delay systems using magnetic disks or drums rotating at high speed, the magnetic heads must work out of contact with the medium. Any variation in the distance separating the heads and medium, such as that which would arise from eccentricity of the disk or drum, will give rise to amplitude modulation of the output signal. Conditions are envisaged in which this effect may be unacceptable. It is here shown that the modulation waveform may be amplified and employed to alter the position of the reproducing head in order to reduce the amplitude modulation.

The system described achieved a reduction of about 26 db in the amplitude modulation present on signals reproduced from a magnetic track recorded on the periphery of a rotating disk.

1. INTRODUCTION.

In a magnetic storage or delay system where the magnetic medium takes the form of a coating on the rim of a disk or drum it is necessary to operate the various heads out of contact with the medium in order to prevent rapid wear of either. A small radial eccentricity of the disk or drum, which is unavoidable even with the finest tolerances, will then produce amplitude modulation of both the recorded and reproduced signals. The output e.m.f., E, from the separated reproducing head is a function of the distance "d" between the gap and the surface of the magnetic track according to the equation.

$$E = E_0 \exp(-2\pi d/\lambda)$$

where λ is the recorded wavelength and E_0 is the output e.m.f. for perfect contact between the reproducing head and medium. In this case E_0 will itself vary around the periphery owing to variations of separation between the medium and the recording head. Thus at short wavelengths the modulation will be serious for quite small variations of separation, for when $d/\lambda = 1$,

$$20 \log_{10} \exp(-2\pi) \simeq 54$$

i.e. a change in output level of 54 db occurs for a change of separation equal to one wavelength.

In the test system described in this report the medium was coated on the rim of a disk rotating at 1500 r.p.m. The signals reproduced from the disk then showed a cyclic amplitude modulation of fundamental frequency 25 c.p.s. A miniature reproducing head was employed, mounted on a cantilever piezo-electric element. The modulation waveform, or error signal, extracted from the reproduced output was fed back to the piezo-electric element in such a way as to move it so that the reproducing head followed the eccentricity of the wheel.

The principal difficulties arose in obtaining a stable servo-loop in the presence of a pronounced mechanical resonance of the cantilever and reproducing head system, the frequency of which occurred inside the pass band of the amplifier. If this mechanical resonance frequency could be sufficiently far removed from the error signal frequency (see Section 4.4.) the degree of servo-control could be still further increased beyond the figure of 26 db obtained with the arrangement described.

2. THE ELECTRO-MECHANICAL TRANSDUCER.

The reproducing head was of small dimensions (about 1 cm. between front and back gaps) and consisted of 10 turns of 32 s.w.g. enamelled copper wire wound on a Ferroxcube former. The head was mounted cantilever fashion on the piezo-electric transducer, which consisted of two thin rods of barium titanate of rectangular section, cemented face-to-face to form a bimorph. The outside faces were sputtered with a conducting layer and electrical contact was secured by light phosphor-bronze springs. The material is marketed by The Plessey Co. Ltd. and bears the trade name of "Casonic". It has a high resistivity (10^{10} ohms per cm^3.) and high permittivity (1200).

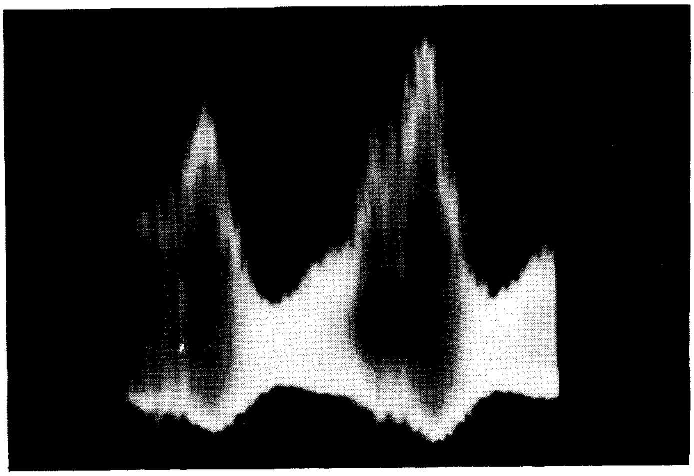
3. THE TEST SIGNAL.

The object of this work, using heads not in contact with the medium, was to reproduce signals down to a minimum recorded wavelength of 0·003 in. (0·076 mm.) largely free of amplitude modulation. The disk, 9 in. (22·9 cm.) in diameter, was driven by a synchronous 3-phase motor at 1500 r.p.m. so that a recorded wavelength of 0·003 in. corresponded to a frequency of 230 kc/s. In order to obviate the necessity of having recording equipment continuously in use, a sinusoidal signal of constant amplitude was recorded permanently on the wheel rim. It was found most convenient to do this by driving the wheel very slowly and recording a lower (audio) frequency signal such that a wavelength of 0·003 in. resulted on the track. As may be seen from the oscillograms reproduced in Figure 1, the signal-to-noise ratio was not very high, mainly because of imperfections in the magnetic coating.

4. THE AMPLIFIER.

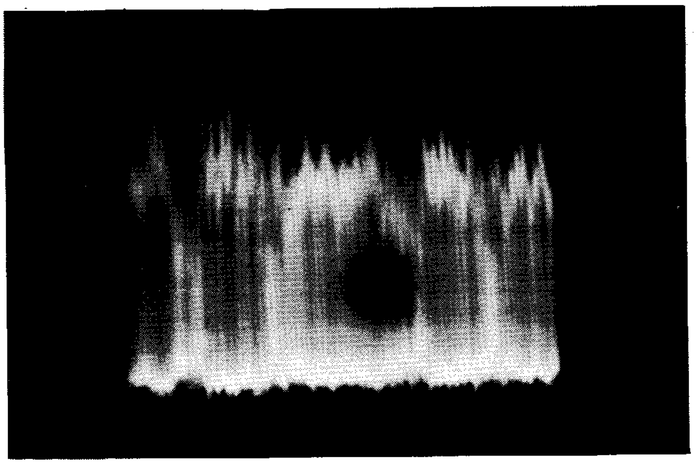
4.1. Signal Frequency Amplification.

The circuit diagram of the complete servo-control amplifier is shown in Figure 2. A step-up, tuned-secondary input transformer coupled the reproducing head to a two-stage resistance-capacity coupled amplifier. The second stage was provided with a negative feedback gain control, affording a range of 10 db variation of gain.



(a)

Oscillogram of 230 kc/s from wheel rim without servo-system. The modulation frequency is 25c/s. Observed at point X in fig 2.



(b)

Oscillogram of 230 kc/s using servo-controlled reproducing head.

Note:-

The asymmetry of the waveform is due to the presence of the demodulator at the only point in the circuit where a sufficiently large signal was available.

Fig. 1

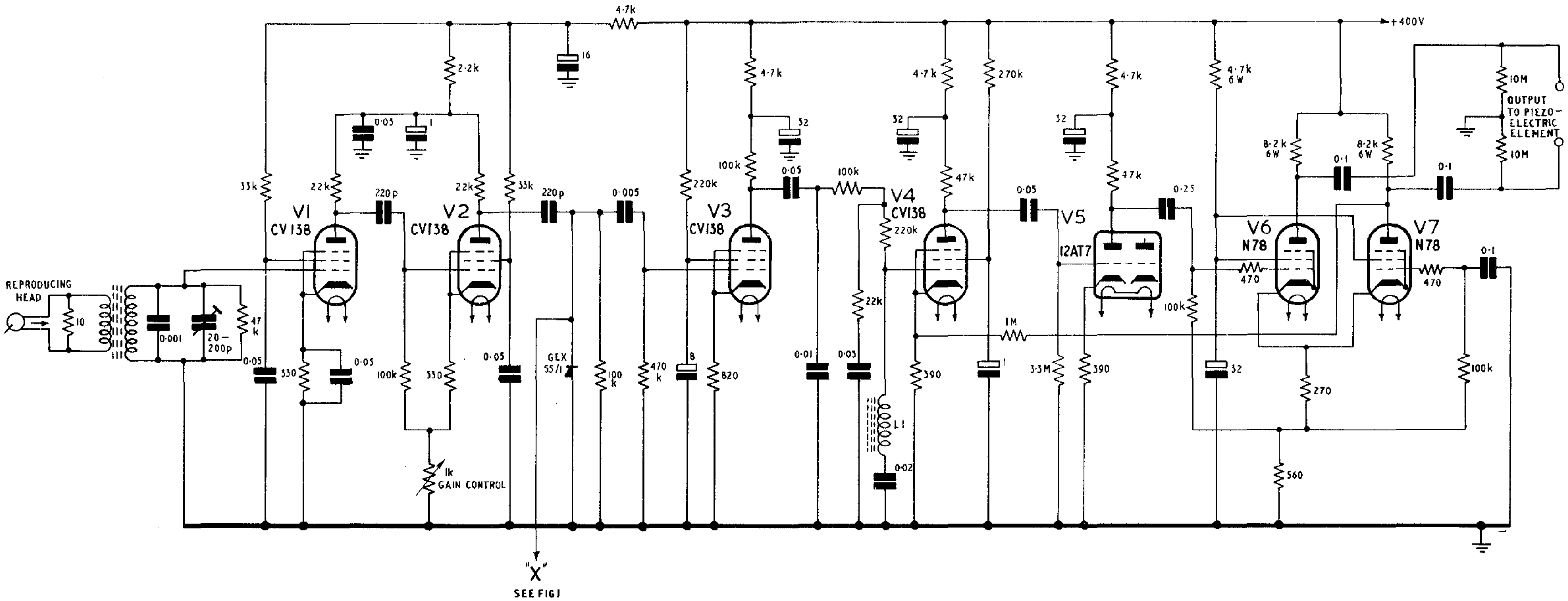


Fig. 2

Servo-control amplifier — circuit diagram.

The e.m.f. from the reproducing head was about 2 to 10 μV (peak-to-peak). This was raised to about 1 volt (peak-to-peak) at the demodulator, which consisted of a simple shunt germanium rectifier, type 6EX 55/1.

4.2. Modulation Frequency Amplification.

The measured static radial eccentricity of the wheel was 0·0003 in.(0·0076 mm.). The transducer element required about 300 volts peak-to-peak across its faces to create this amount of deflection of the reproducing head. A push-pull resistance-capacity coupled output stage was employed for the drive, since the transducer acted like a resistance of about 20 M Ω in parallel with a capacitance of 0·001 μF, except at the mechanical resonance frequency, when the apparent resistance fell to about 3 MΩ. The output stage was preceded by a three-stage resistance-capacity coupled amplifier. A large amount of negative voltage-feedback was employed on the final stages and the gain/frequency characteristic of the whole amplifier was closely controlled to meet the stability requirements, described more fully in Section 4.3.

4.3. Servo-Loop Stability.

Nyquist's general stability requirement[1] for a negative feedback system states that the complex plot of the open loop transfer function shall not encircle the point (-1, 0) on the Argand diagram. In a system of linear, passive elements, such as that under consideration, which is stable in the open-loop condition, this criterion is achieved if the slope of the open loop gain/frequency characteristic does not exceed 6 db/octave in the region of unity gain.[2, 3] Since the loop of this system included an electro-mechanical transducer, it was necessary to measure the deflection/frequency response of this separately, The result is shown in Figure 3, which also shows the characteristic of the amplifier plotted in the form of an attenuation/frequency curve. It is the difference between the slopes of these two characteristics which must not exceed 6 db per octave in regions of unity gain. As the servo-control was required to operate over the range 25 to 50 c.p.s. the frequencies outside these limits had to be progressively attenuated in accordance with the requirements stated above. In practice it was necessary to provide a stability margin of at least 2 to 3 db per octave, and in this case, for 30 db of servo-feedback, the frequency characteristic of the loop had to be controlled from 0·5 c.p.s. to about 800 c.p.s.

4.4. Mechanical Resonance of Transducer.

To compensate for the mechanical resonance of the transducer and head assembly a series-resonance filter with the appropriate Q(20) was inserted in the amplifier. The greatest loop stability was obtained when the resonance frequency of the filter was slightly lower than that of the transducer, as shown in Figure 3. In the arrangement used it was not possible to raise the mechanical resonance frequency above 500 c.p.s. because the mass of the reproducing head was fixed, and the permissible stiffness of the transducer was limited by the minimum useful voltage sensitivity which could be employed.

5. TRANSDUCER LIFE TEST.

The transducer elements were found to be somewhat fragile. It was there-

fore decided to carry out a life test. Six elements were mounted by clamping at one end and driven from a source of alternating voltage which caused them to vibrate at 50 c.p.s. Three elements were caused to vibrate with a peak amplitude of $1 \cdot 5 \times 10^{-3}$ in. and three with a peak amplitude of 3×10^{-3} in. In each set, one element was end-loaded with a mass equivalent to that of the reproducing head. After 1,300 hours continuous running, during which the elements executed 234 million vibrations, no failures had occurred, and the test was discontinued.

6. CONCLUSION.

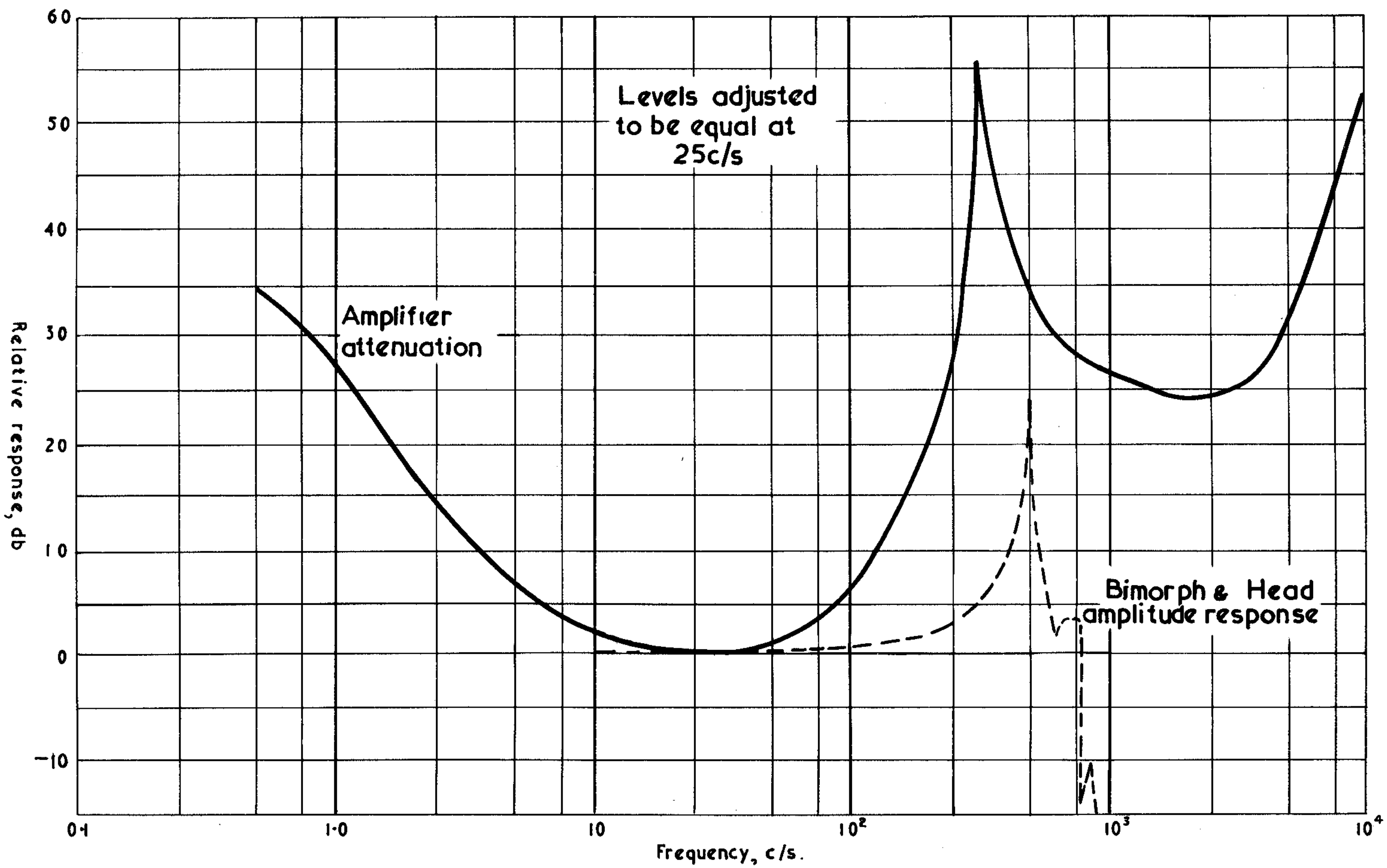
In a magnetic recording system where amplitude modulation of stored signals results from varying track-to-reproducing head distance, the modulation may be reduced by some 26 db by employing servo-control of a piezo-electric head-mounting element. This figure for modulation reduction could be improved upon if the mechanical resonance frequency of the transducer was further removed from the error signal frequency. The use of the device may be necessary in certain magnetic storage applications, such as television frame-delay systems, where unwanted amplitude modulation of the stored signals would prove embarrassing.

7. REFERENCES.

1. "Regeneration Theory", H. Nyquist, Bell System Technical Journal, Vol. 11, January 1932.

2. "Network Analysis and Feedback Amplifier Design", H.W. Bode, D. Van Nostrand Co., N. York, 1945.

3. "Servomechanisms and Regulating System Design", Vol. 1, H. Chestnut and R.A. Mayer, J. Wiley and Sons, Inc., N. York, 1951.



60
50
40
30
20
10
0
−10
Relative response, db
0·1
1·0
10
10^2
10^3
10^4
Frequency, c/s.
Levels adjusted
to be equal at
25c/s
Amplifier
attenuation
Bimorph & Head
amplitude response

Fig. 3

APPENDIX

Input Transformer Details.

Core Assembly:	Neosid Type T10.
Primary:	1·5 turns 36 s.w.g. En.S.S.C. copper wire.
Secondary:	80 turns 36 s.w.g. En.S.S.C. copper wire.

Inductor L_1 Details.

Core Assembly:	Ferroxcube Type LA11.
	3,500 turns of 38 s.w.g. D.S.C. copper wire pile wound, flexible end leads provided.
D.C. Resistance:	280 Ω
Inductance:	9·5 Henries (no superimposed direct current.)